Policy and Regulatory Recommendations to Support a Least-Cost Pathway for India's Power Sector

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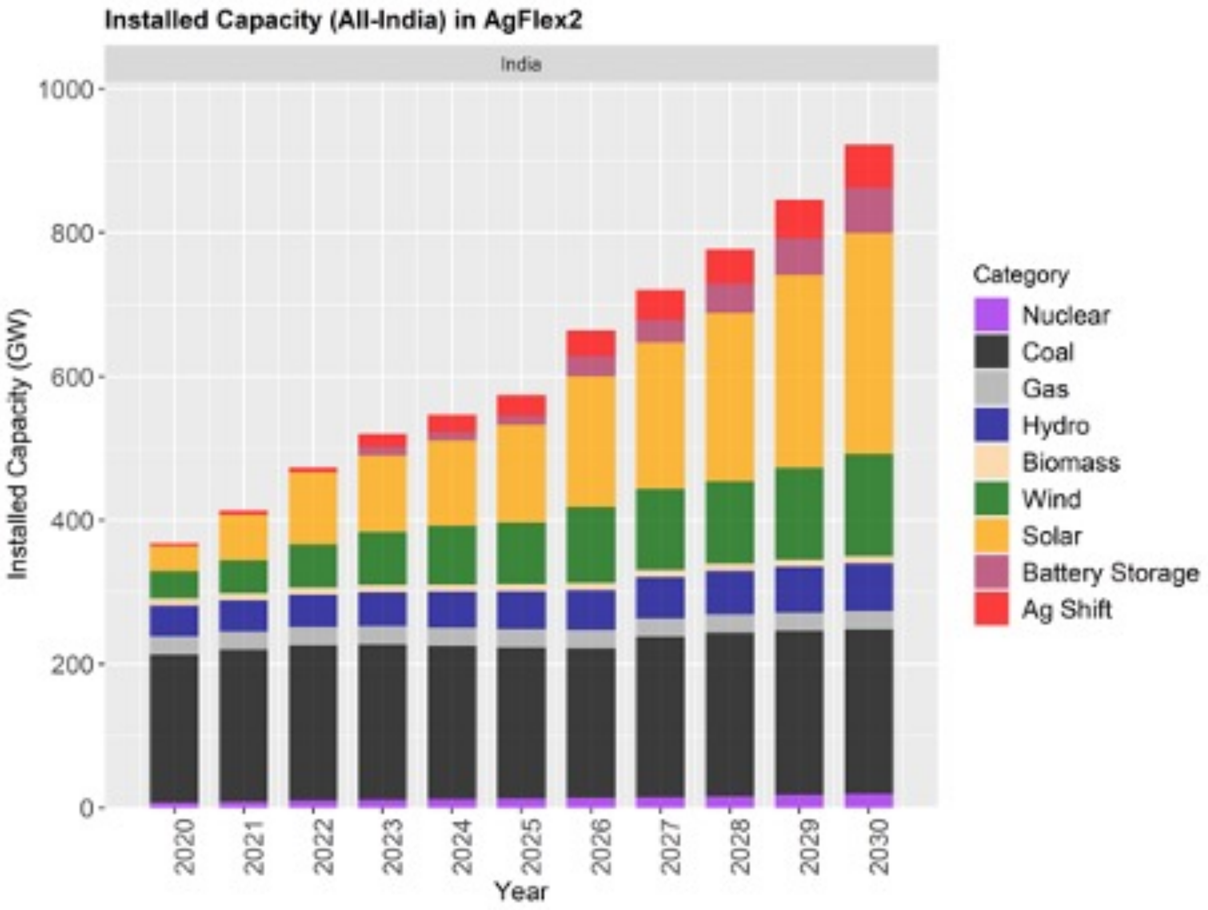
Policy and Regulatory Recommendations to achieve the Least-Cost Pathway

- **Resource Adequacy (RA) Framework**
  - National study to determine optimal resource mix for given demand; reserve margin study to determine RA requirement
  - Institute RA program at the national level, with monthly or seasonal RA requirements allocated to the states; facilitate capacity sharing among states
  - In the longer term, move towards national capacity markets with national pool for energy settlement (e.g., Market-Based Economic Dispatch, MBED)
- **Planning and procurement**
  - Integrate RA requirements into discom/state planning and procurement
  - "All-source" procurement for new resources at state/discom level to account for the interactions among different resources and arrive at least-cost mix
- **Markets and system operations**
  - Adjust electricity market rules to enable storage to provide and be compensated for its full functionality
  - Better align market and system operations to enable efficient ancillary services markets and manage potential transmission congestion; accelerate implementation of MBED

450 GW of renewable capacity would be cost-effective to meet India's load in 2030

National study under the Flexible Resources Initiative (FRI) assessed a least-cost resource mix for the Indian power sector up to 2030, through comprehensive system expansion and hourly operational modeling at individual power plant level



- The least cost pathway up to 2030 consists of >450 GW_{DC} of RE + flexible resources: ~60GW energy storage, 60GW load shifting, flexible operation of 25 GW gas, >140GW of additional interstate transmission, & national wholesale electricity markets
- 23 GW of net addition to the coal capacity is cost effective by 2030 (may be higher in case RE/storage costs do not drop or deployment barriers)
- The complementarity of flexible resources working in tandem is crucial for maintaining grid dependability in view of high RE penetration
- Policy and regulatory measures would be required to realize this optimal resource mix

Current Planning & Procurement practices won't get us to least cost mix

Rapid changes in this decade will aggravate current challenges:

- Load shape is changing, with additional space cooling load (e.g. Delhi), and EV charging/ electrification of industry in medium term, making bottom-up demand forecasting critical
- Increasing renewable penetration is changing system operations: capacity contribution of RE to peak is minimal
- States procuring resources to meet individual state level peak demand results in low utilization of assets and inflated system costs
- Large-scale sharing of resources amongst states not practiced
    - Existing mechanisms: inter-state banking, sharing between beneficiaries of ISTS plants
    - Streamlined sharing of resources would be critical to keeping costs low in 2030
- Current procurement practices do not have a way to account for interactions among different resource types, including storage and demand response, as well as changes in load profiles

System operators would need to ensure sufficient firm capacity on the grid at all times

=> a robust and nuanced approach to Resource Adequacy would be needed going forward.

Sharing of resources key to leverage load and resource diversity

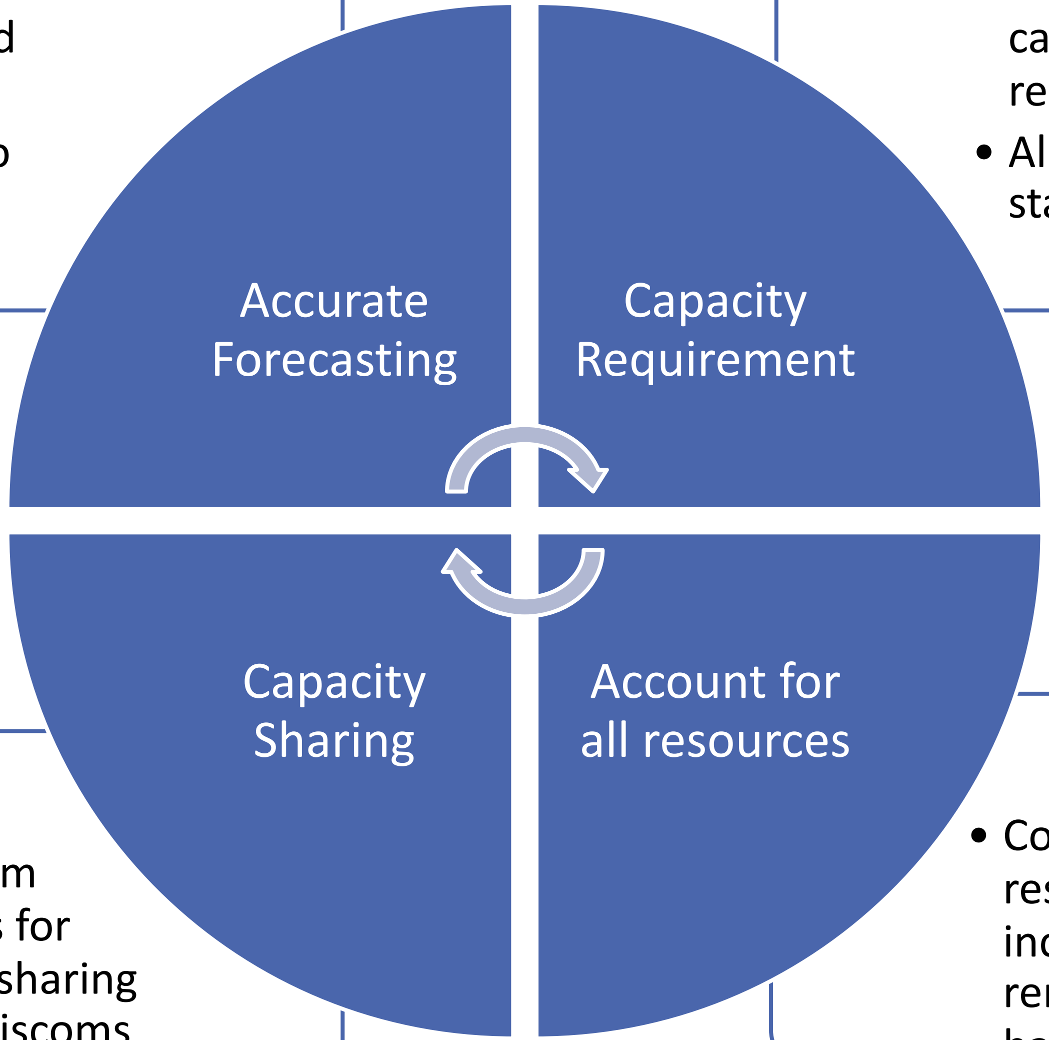
- Capacity requirement
  - Resource Adequacy (RA) requirement based on national coincident peak (CP) plus a planning reserve margin (PRM)
  - PRM: generation capacity needed in addition to forecasted national CP for reliability
- Capacity sharing
  - States can import from other states during their peak hours as plenty of capacity is available on the system
  - RA contracts would include competitive purchase of capacity, and transfer of scheduling rights to buyer

System CP (2018)	**MW**	**171,690**		
PRM	%	15%		
Total RA requirement	MW	197,443		
System CP hour	hour	6260	(Sep 18, 2018)	
	Delhi	**Maharashtra**	**Karnataka**	**Jharkhand**
Load during system CP	4,952	20709	8954	972
Share of system CP	3%	12%	5%	1%
RA requirement	5,695	23,815	10,297	1117
State peak demand	6,931	24,570	10,648	1270
State peak hour	4,576	6924	2075	8708
System load during peak hour	154,626	157,838	147,320	148,618
Required RA imports	(1,237)	(755)	(351)	(153)
Available capacity during state peak hour	42,817	39,606	50,124	48,825

Resource Adequacy (RA) framework would help address these issues

- Guidelines for state load forecasts
- Roll up to national forecast

- Assess required capacity for reliable system
- Allocate to states



- Short-term contracts for capacity sharing among Discoms

- Count all resources including renewables and battery storage

RA Program based on international experience

- A national RA program would build upon ongoing reforms, integrating with state level regulatory processes
- RA programs in the US include several steps as below; capacity markets are bilateral or have regular auctions for RA capacity in which the system operator acts as the buyer

Reserve requirement study	Capacity crediting	RA requirement allocation	RA markets	RA compliance penalties
Sets total RA requirement based on CP + PRM	Set capacity credits for different resource types	Allocate RA requirement to states/discoms	Discoms comply with RA requirements through market-based transactions	Assess penalties for deficiencies and availability
Would create a PRM (CEA NEP does not have an explicit PRM); would create standards for state load forecasting	Would make capacity crediting for RE, hydro, storage the norm (some states starting to do this)	Would create explicit mandatory RA requirements for each state, as allocation of national RA requirement	Would create decentralized markets for RA compliance, via transfer of scheduling rights between discoms or new contracts	Would establish penalties for non-compliance, using a multiple of the cost of new resources

RA Program Design Options

- RA program can be designed at the national or regional/state level
- Options differ in the total amount of capacity need (RA requirement)
- Assumption: in the near term, states/discoms must be able to continue to schedule energy up to their peak demands, until MBED is implemented

Key results from RA program design analysis (2018 data)
National annual CP: 171,690 MW

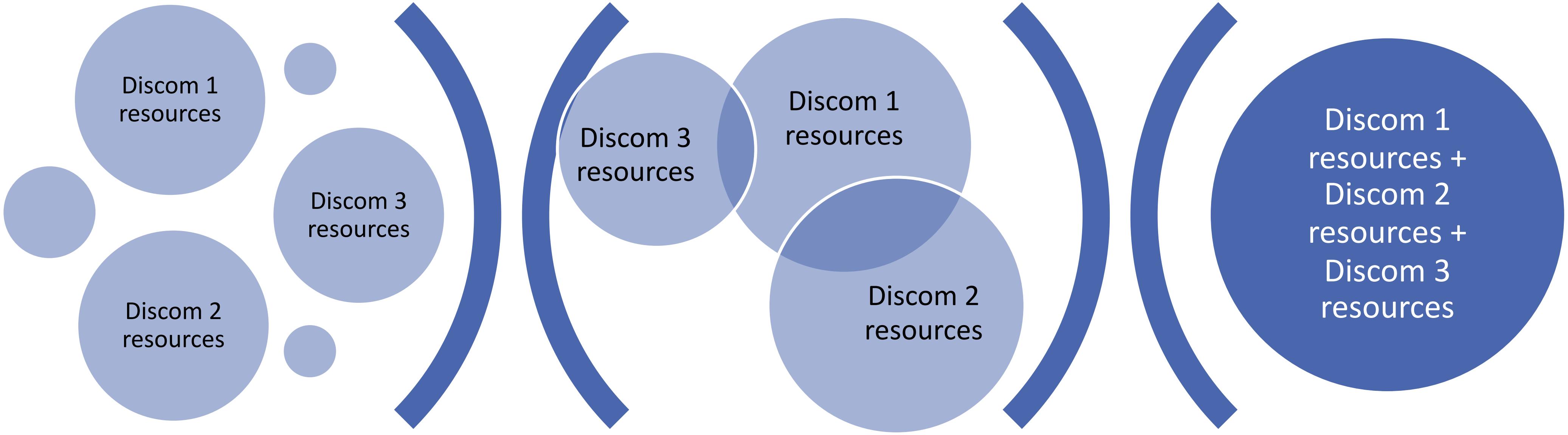
RA Program Scope	Compliance	RA Requirement (MW)
National	Monthly	197,443
National	Annual	Infeasible
Regional	Annual	220,225
State	Annual	239,652

- Program scope refers to the coincident peak forecast used; all designs used a 15% PRM
- Compliance refers to the period over which states/discoms are required to demonstrate compliance; seasonal and monthly compliance require more regulatory effort but allow resource sharing
- The "national – annual" design is infeasible because of state/discom energy scheduling needs

RA markets can evolve with time

Short-term

- Discoms need to have scheduling rights on all resources they need
- RA contracts could have competitively bid fix cost and transfer of scheduling rights
- Existing platforms eg DEEP could facilitate these contracts for capacity, with energy
- RA contracts enable utilization and sharing of existing assets



Current framework

Capacity sharing through bilateral RA contracts

Capacity Market

Long-term

- A centralized market with capacity only contracts could be implemented
- All such capacity would have must-offer obligations in energy markets, to ensure availability at time of Discom need

Resource Adequacy Recommendations

- Create national planning guidelines for state load forecasts, to ensure a consistent national load forecast.
- Develop an annual or biennial reserve margin study that sets a national RA requirement.
- Allocate the national RA requirement to states with year-ahead compliance.
- Develop transparent methods for calculating the contribution of different kinds of resources to RA requirements.
- Allow states and Discoms to comply with RA requirements through self-supply and bilateral markets for RA capacity that transfer scheduling rights in the nearer term, to facilitate sharing of capacity resources.
- Develop RA deficiency penalties to enforce compliance with RA requirements and incentives to ensure generator availability.

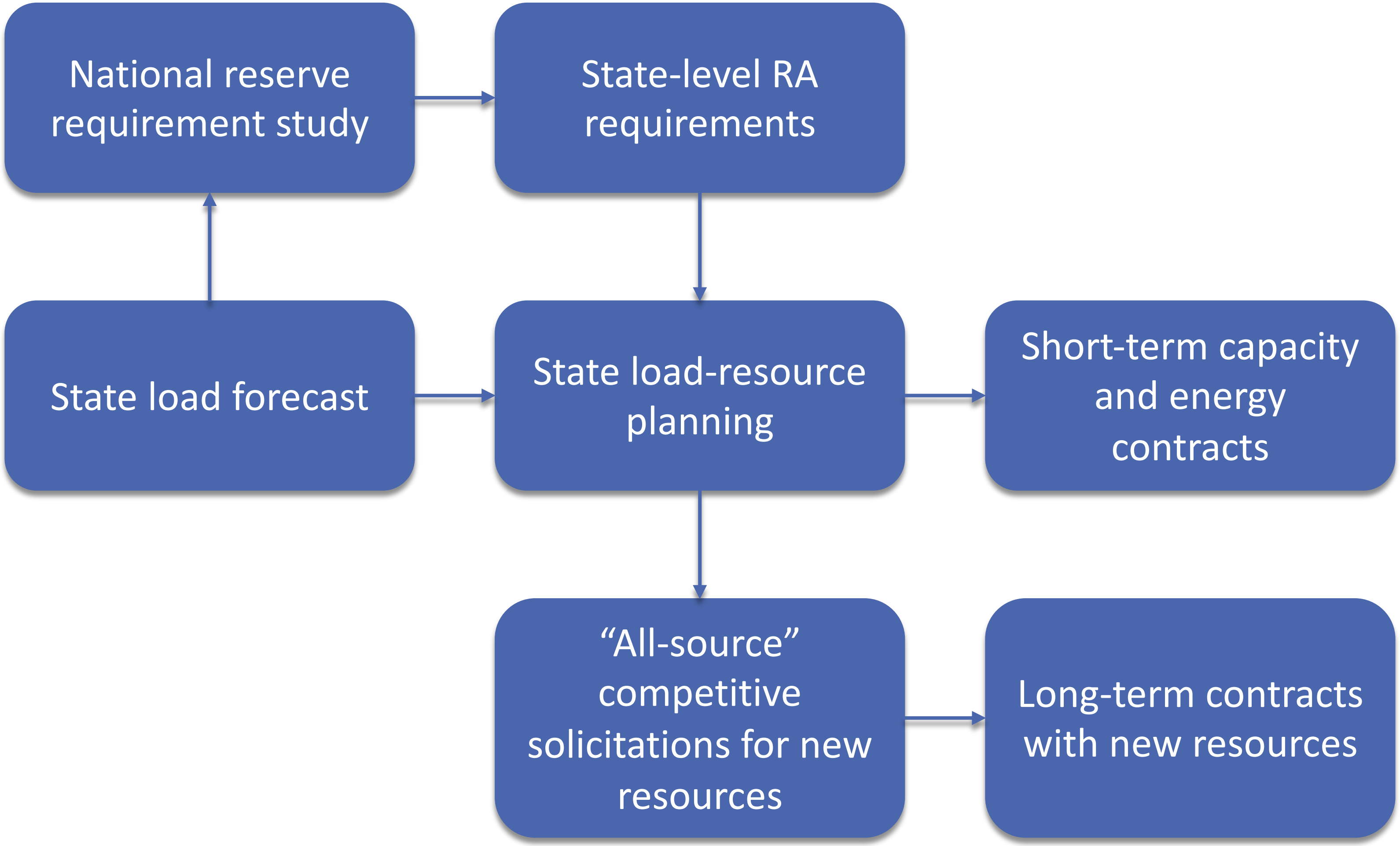
In the longer term:

- Adapt RA mechanism to changes in electricity markets, industry structure, and emerging technologies. For example, this might include developing a national RA market for capacity-only contracts.
- Develop probabilistic methods for capacity crediting.

RA Program would integrate with State/Discom Procurement

- States would meet their RA requirements through short-term contracts with existing resources or long-term contracts with new
- States would conduct all-source procurement, evaluate bids using economic analysis tools (e.g., capacity expansion models)

=> States would construct least-cost portfolios of RE, thermal, and storage resources that meet RA requirements



Resource Planning and Procurement Recommendations

- Integrate RA requirements into state/Discom determination of resource needs.
- Pilot all-source competitive procurement process, in which all eligible resources, including energy storage and demand-side resources, compete in a single competitive solicitation.
- Build capacity of states/Discoms to use engineering-economic models to evaluate economics of different resources.

In the longer term

- Expand all-source competitive procurement nationwide and integrate long-term procurement, short-term market prices, and transmission expansion

Resource planning Identify resource needs	Discom/state assess resource needs based on RA requirement
All-source competitive solicitation Solicit bids for new projects	All resources allowed to participate in discom/state's competitive solicitations for new resources
Portfolio evaluation Evaluate bids based on their net market value	Discom/states evaluate bids in terms of net market value, similar approach to LBNL modeling study
Project selection Select new projects based on portfolio evaluation	Portfolio of new resources that minimizes total costs and meets RA requirement will also provide required amount of flexibility at least-cost

Markets and System Operations Recommendations

Markets are important source of low cost system flexibility: liquid markets and closer alignment between markets and system operations will enable faster and cost-effective response to load changes, without compromising system reliability

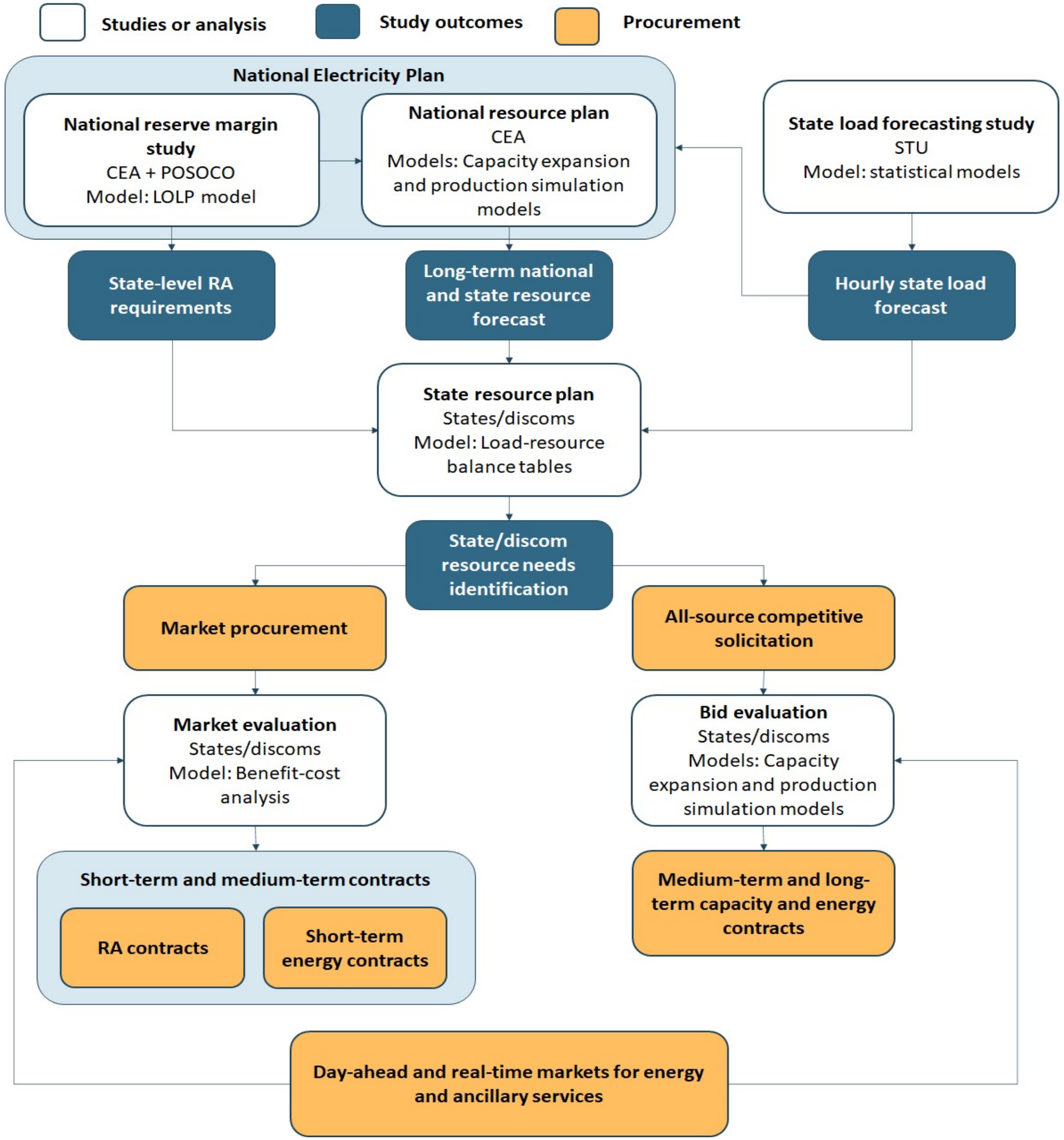
Near term (1-3 years)

- Complete implementation of day-ahead and ancillary service market reforms
  - Demonstrate value of markets and least-cost operations to states
- Review scheduling and market participation rules for energy storage to ensure that its full functionality can be recognized, utilized, and compensated through markets.

Longer term (4-10 years)

- Develop security-constrained 5-minute economic dispatch in real-time markets, using market-based congestion management
- Longer-term goals:
  - Closer alignment between markets and system operations, efficient use of transmission system, incentives for efficient resource siting decisions

Recommendations form a coherent Regulatory Framework



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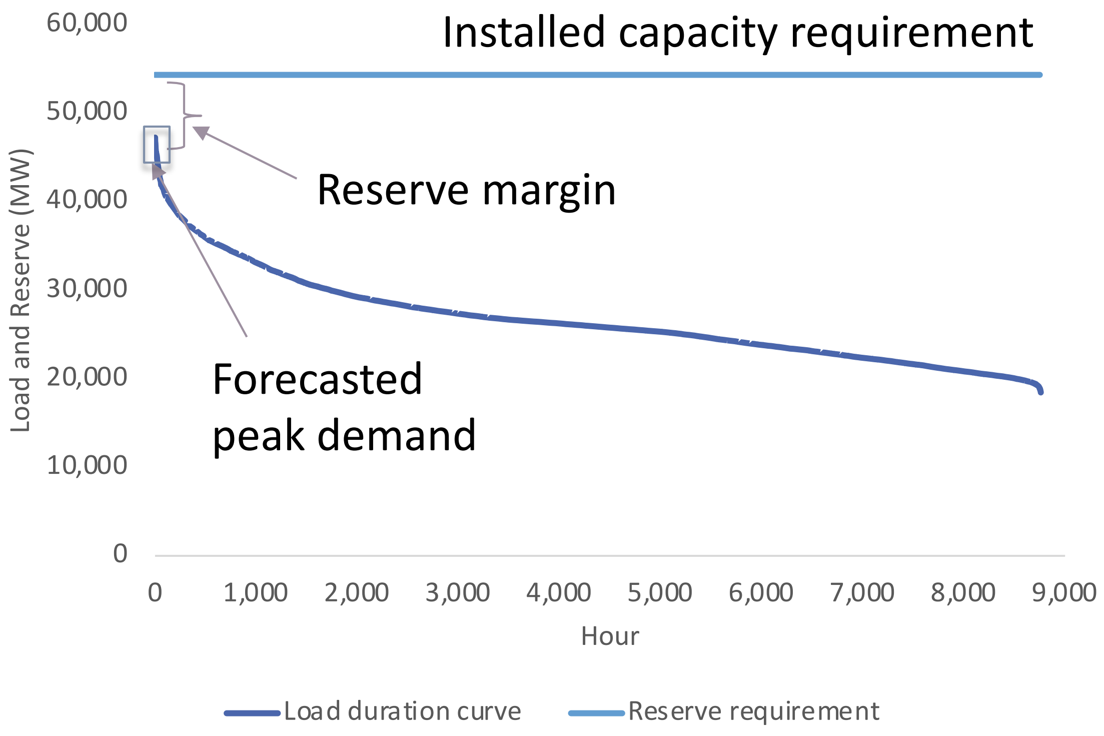
ADDITIONAL MATERIAL

Reserve Requirement Study

Recommendation: Develop a reserve requirement study process, an annual or biennial reserve margin study that sets a national RA requirement.



- Reserve margin study sets a reserve margin, based on a reliability (loss-of-load expectation) target
- The total amount of required capacity (installed capacity requirement) is the forecasted peak demand plus the reserve margin

Example: Load Diversity Benefits

- Developing RA requirements at a regional or national level will lead to cost savings from load diversity
  - The larger the area, the greater the savings

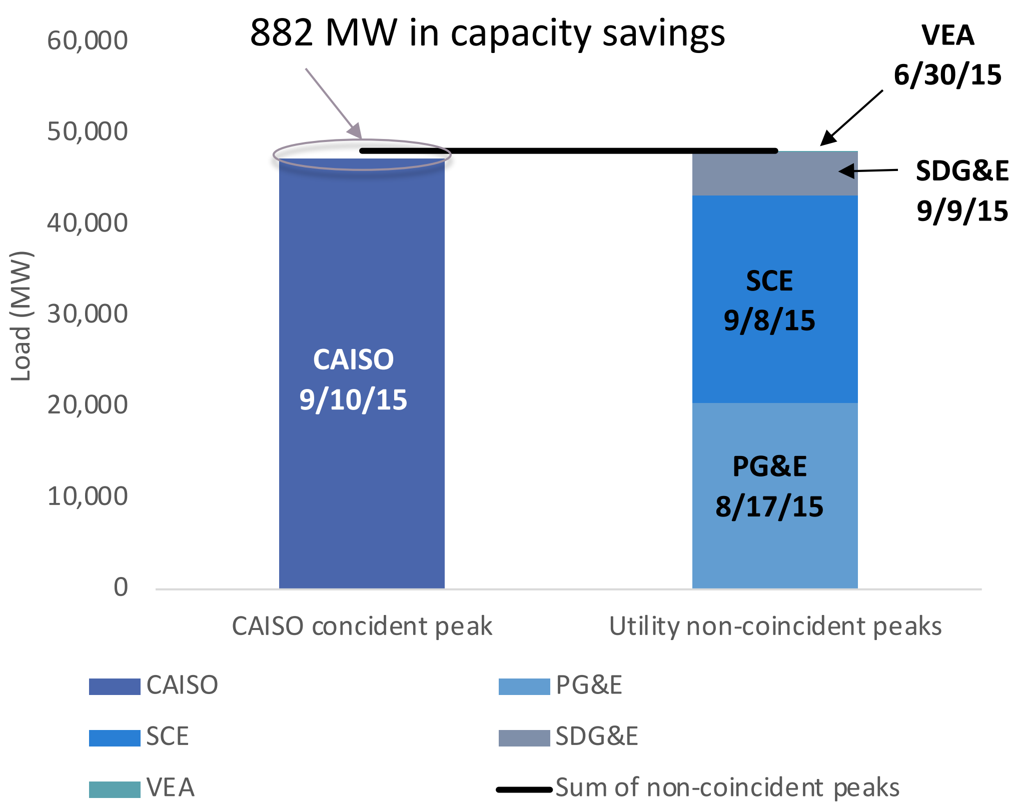


Figure illustrates load diversity benefits in California. California's RA standard is based on the CAISO coincident peak rather than individual utility peaks, leading to a capacity savings of 882 MW and tens to hundreds of millions of dollars in compliance savings. Dates are peak load dates (2015 data). SCE is Southern California Edison, PG&E is Pacific Gas & Electric, SDG&E is San Diego Gas & Electric, VEA is Valley Electric Association.

Capacity Crediting

Recommendation: Develop transparent methods for calculating the capacity contribution of demand response, energy storage, hydro, solar, and wind to resource adequacy requirements, to avoid overbuilding or underbuilding.

- Capacity credit is amount that different classes of resources contribute towards RA requirements
  - For instance, a 50 MW solar farm with an NQC of 40% will contribute 20 MW
- Important to credit non-thermal resources to avoid over-building

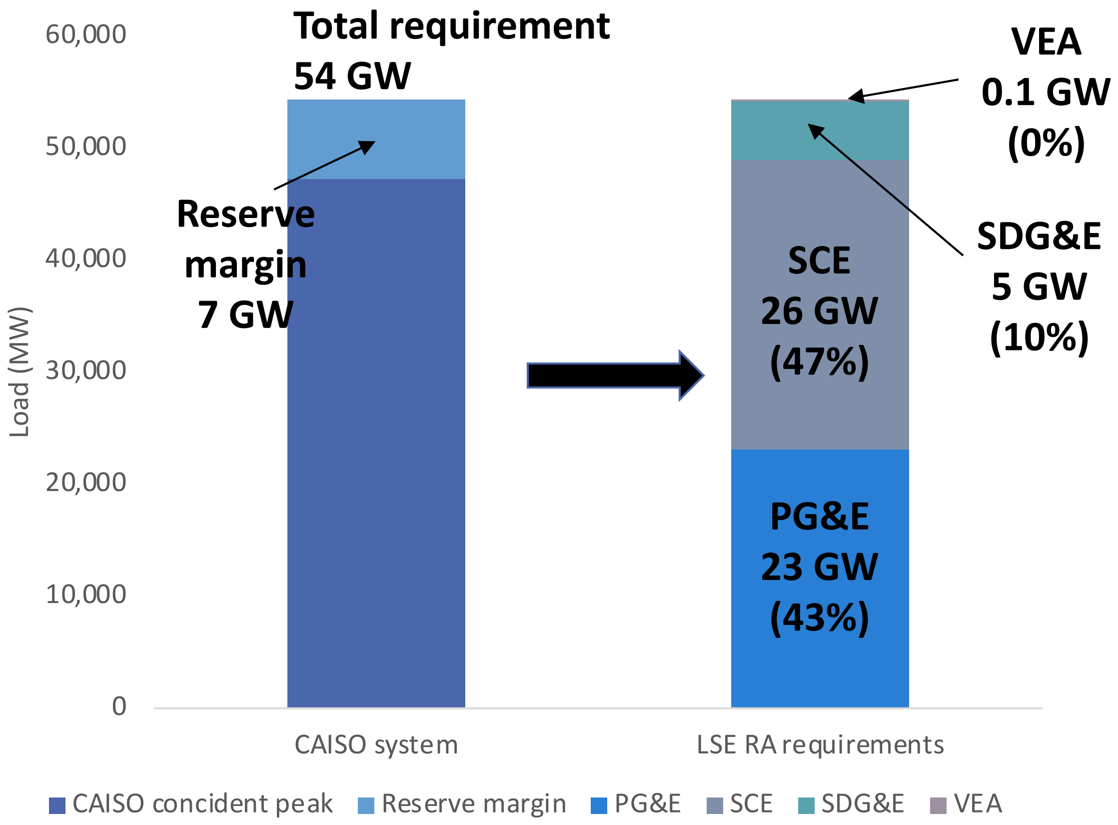
Illustrative example of capacity credits in PJM*

Resource	Average Value	Method
Demand response	Nameplate	Performance enforced through non-performance penalties
Energy storage	Unit-specific	Based on simultaneous output capability during past 15 years of summer peak conditions
Hydroelectric	Unit-specific	Expected streamflow and head during past 15 years of summer peak conditions
Solar	38-60%	Capacity factor during summer peak hours over past three years
Wind	~15-18%	Capacity factor during summer peak hours over past three years

** ISOs have different approaches to capacity crediting*

Resource Adequacy Requirements

Recommendation: Establish seasonal or annual resource adequacy requirements for LSEs based on their shares of regional or national coincident peak demand, to ensure that the resource adequacy standard is met.

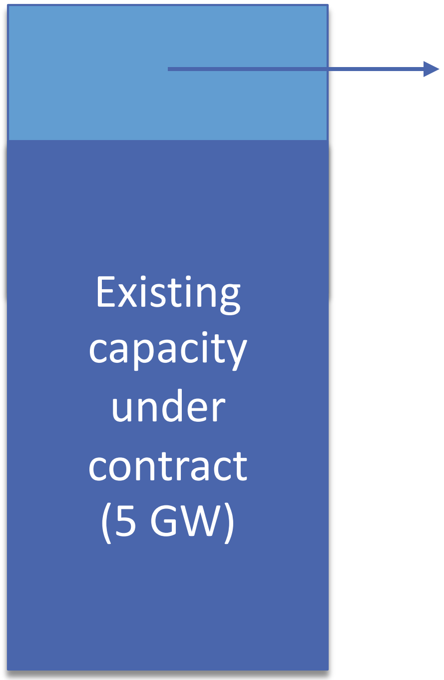


- Allocation of RA requirement to LSEs is typically based on forecasted LSE share of peak demand (“load ratio share”)
- LSEs must demonstrate sufficient capacity to meet requirement

Bilateral Capacity Markets

Recommendation: Allow LSEs to comply with resource adequacy requirements through self-supply or bilateral transactions, to reduce the cost of meeting the standard.

Total requirement (7 GW)



Capacity shortfall (2 GW)

LSE must procure from other LSEs that have surplus, procure from uncontracted generators, or procure new resources

- LSEs could buy (if they are short) or sell (if they are long) access to resources through bilateral transactions with other LSEs or generators
- Contracts will be in Rs per kW per unit time (Rs/kW-yr or Rs/kW-mo), if for capacity only.
- Capacity contract prices will be based on a unit's fixed costs minus contract and market revenues
- Transfer scheduling rights in the nearer term- contracts might need to have both capacity and energy component

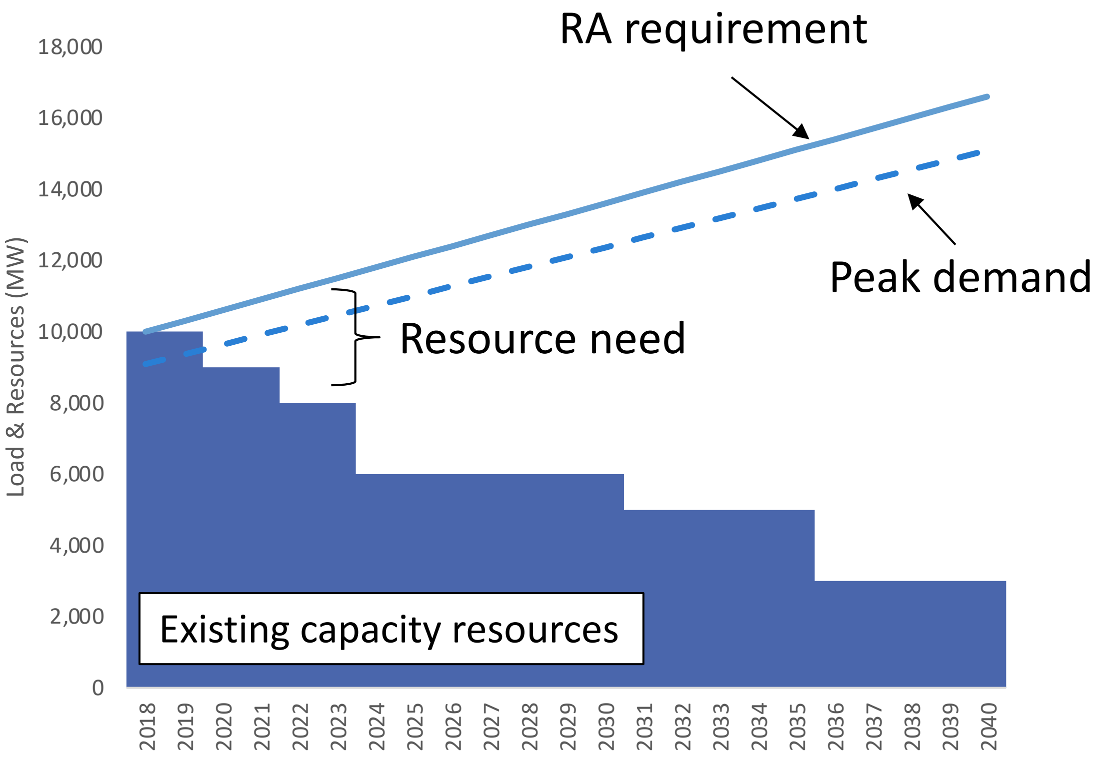
Deficiency Penalties and Availability Requirements

Recommendation: Develop RA deficiency penalties to enforce compliance with RA requirements and incentives to ensure generator availability.

- Deficiency penalties are assessed on LSEs that do not demonstrate compliance with their RA requirement
  - Penalties are typically based on marginal replacement costs, can be designed to be revenue neutral
- In the longer-term, with implementation of Market Based Economic Dispatch (MBED), must-offer requirements would be possible
  - must-offer requirements ensure that resources committed to meet RA requirements are available to the system when needed
  - In the United States, resources with obligations to provide capacity typically have a must-offer obligation in day-ahead markets

Resource Planning & Procurement

Recommendation: Establish standard practices for determining resource needs in discom/state resource planning, to ensure that procurement of new resources is aligned with resource adequacy requirements.



- Resource needs (capacity) are the gap between RA requirement and existing capacity resources
- In the U.S., needs are identified through resource planning process that includes load forecasting
- Resource needs will be the quantity (MW) solicited in RFPs

All-Source Competitive Procurement

Recommendation: Pilot an all-source competitive procurement process in one or more states, in which all eligible resources, including energy storage and demand-side resources, compete in a single competitive solicitation.

- All-source solicitation invites bids from range of resource types to meet resource need
- Bids evaluated on a net market value (benefits – costs) basis
- Select bids that minimize portfolio cost while meeting criteria for risk
- Minimizing portfolio cost will also provide economic level of flexibility

RFP Responses by Technology

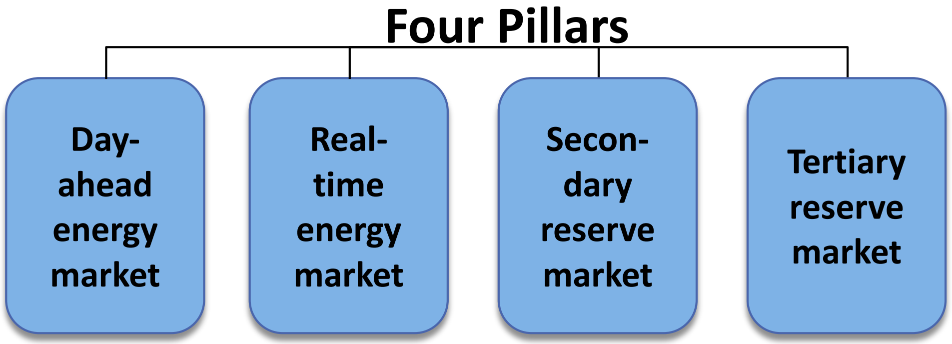
Generation Technology	# of Bids	Bid MW	# of Projects	Project MW	Median Bid Price or Equivalent	Pricing Units
Combustion Turbine/IC Engines	30	7,141	13	2,466	$ 4.80	$/kW-mo
Combustion Turbine with Battery Storage	7	804	3	476	6.20	$/kW-mo
Gas-Fired Combined Cycles	2	451	2	451	[redacted]	$/kW-mo
Stand-alone Battery Storage	28	2,143	21	1,614	11.30	$/kW-mo
Compressed Air Energy Storage	1	317	1	317	[redacted]	$/kW-mo
Wind	96	42,278	42	17,380	$ 18.10	$/MWh
Wind and Solar	5	2,612	4	2,162	19.90	$/MWh
Wind with Battery Storage	11	5,700	8	5,097	21.00	$/MWh
Solar (PV)	152	29,710	75	13,435	29.50	$/MWh
Wind and Solar and Battery Storage	7	4,048	7	4,048	30.60	$/MWh
Solar (PV) with Battery Storage	87	16,725	59	10,813	36.00	$/MWh
IC Engine with Solar	1	5	1	5	[redacted]	$/MWh
Waste Heat	2	21	1	11	[redacted]	$/MWh
Biomass	1	9	1	9	[redacted]	$/MWh
Total	430	111,963	238	58,283		

Figure shows summary statistics from all-source competitive procurement by a Colorado utility; utility selected portfolio based on evaluation of these bids.

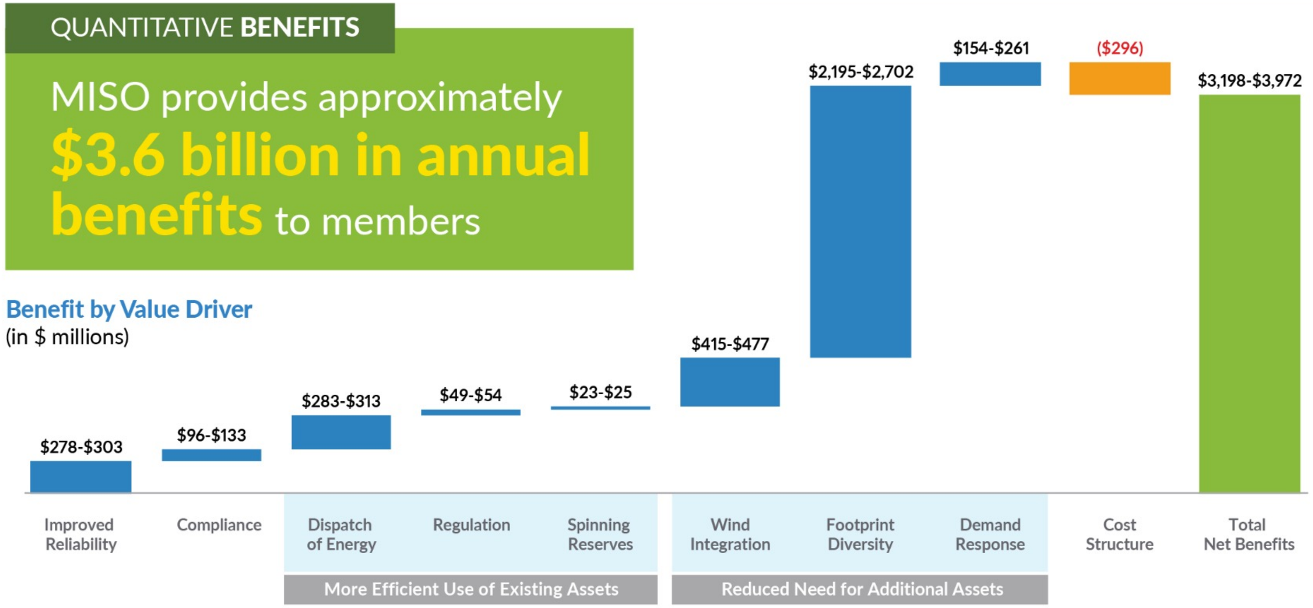
Market Foundations

Recommendation: Complete implementation of day-ahead, and Ancillary Service market reforms.

- U.S. experience has been that energy and ancillary services markets have been the primary driver of power system flexibility



- U.S. experience has been that value propositions are important for creating buy-in among participating states and utilities



Storage Participation Model

Recommendation: Review scheduling and market participation rules for energy storage to ensure that its full functionality, can berecognized, utilized and compensated through markets.

- U.S. ISOs have created "resource models" for storage participation in markets
  - CAISO has "non-generator resource," PJM has "energy storage resource"
- Resource models enable:
  - Full participation in energy, AS, RA markets
  - Bid-based schedule and dispatch optimization
  - Option to allow ISO to optimize state of charge (for batteries)
- ISOs are developing new products
  - "Spread bidding" in CAISO
- Energy storage participation in India and the United States will be different due to differences in market designs

Energy storage (pumped hydro, batteries, thermal) is a unique resource, can act as a load or a generator

Figure shows an illustrative bid curve